I became an assistant professor at the Michigan State University, DOE, PRL when I was 39 years old. My colleagues and mentors at the PRL provided a local environment that was both stimulating and challenging, encouraging me to be the best possible scientist I could be. What I achieved was also due to the chance of time. I am a product of the age of molecular biology and now genomics with its rapidly expanding knowledge bases and incredible information systems made possible by technological growth. This lucky moment in history has allowed all of us here today the privilege to be pioneers of new and fascinating frontiers.

I also sincerely believe in giving back to the system from which I benefited so greatly. Although my primary interest is still my lab and my science, I accepted several big responsibilities of leadership within our field. I now work toward many objectives on behalf of a scientific community as well as my own personal interests. At the PRL, I learned not only how to run a lab and to do science but also how to be an effective and thoughtful leader. Only later when I became an Editor in Chief of the largest plant journal, *Plant Physiology,* and a founding director of the Center for Plant Cell Biology, and later a director of the Institute for Integrative Genome Biology at the University of California Riverside did I realize how essential these years at the PRL were for me. As with my past work, my current work depends upon the efforts of many, more numerous than I can ever list — my students, postdocs, friends, and colleagues, for whom I feel much gratitude.

I hear very often now about what an exceptionally difficult time it is for young people, and I agree that it is not easy. But it is never ever easy! I never dreamt of being where I am today, but I always worked very hard and loved doing science. The reason I am sharing a little bit of my story with you is because I want young people to see that, with all the pluses and minuses, we are very fortunate to live in this incredible country. There is no place in this world that offers an opportunity to reach for the stars — one only needs to work hard, be creative and love what he/she is doing.

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Quick guide

Carnivorous plants

Rainer Hedrich

What are carnivorous plants? Have you seen the film *The Little Shop of Horrors*? This cult horror comedy is about a florist's assistant who cultivates a plant that feeds on human flesh and blood. Carnivorous plants are plants that survive nutrient-poor habitats by feeding on trapped animals. Imagine you're a small animal all of a sudden getting on a trap of a carnivorous plant, how would you become the next meal of the green flesh-eater?

Why become a green flesh-eater? Botanical carnivory is associated with plants that master survival in nutrient-poor habitats lacking nitrogen, phosphate, sulphur and minerals. These specialists often do not even bear true roots — instead leaves are modified to accommodate a trap function on either aerial or underground/submersed parts. Some species of carnivorous plants utilize passive traps, while others have evolved active traps to capture prey. Passive traps, of the flypaper type, have glandular hairs that produce a sticky glue-like substance to arrest their visitors. Pitcher plants, as another example, grow pitfall traps with a slippery rim to direct prey into a digestive moiety where gland cells take up prey-derived nutrients.

How do carnivorous plants 'hunt'? The hunting skills of active carnivores possessing snap, bladder, or catapult tentacle traps are the most advanced. These sophisticated capture organs allow the plants to hunt even very mobile insects. Capture organs have mechanical and electrical sensors, which trigger rapid closure of the trap. When prey touches the sensor, viscoelastic energy stored in the open trap state is released within a blink of an eye. In the Venus flytrap *Dionaea muscipula* — the Darwin Plant — the leaf tip develops into a bilobed snap trap, each trap lobe equipped with three sensory hairs. When visitors inadvertently bend these trigger hairs, mechano-receptor cells are stimulated to fire an electrical impulse, which travels as an action potential along the entire trap surface. A second action

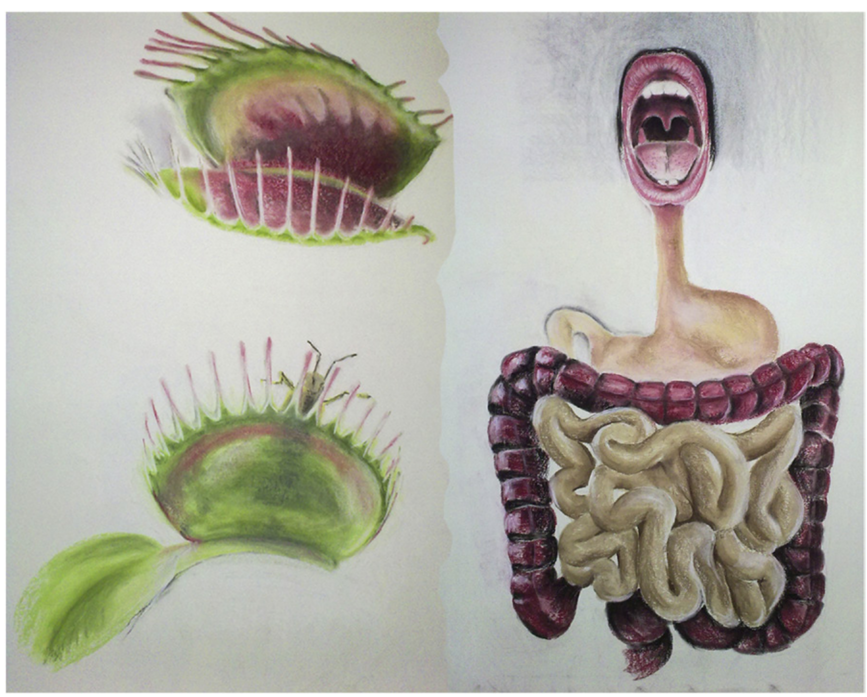

Figure 1. Carnivorous plants.
When we chew and then swallow meat, we stimulate glands (pancreatic acinar cells) to secrete hydrochloric acid and proteases. Amino acids released into the human stomach by the acidic lytic sap are forwarded to and taken up by the intestine. When compared with the human endocrine system, the Venus flytrap also operates as a mouth, stomach and intestine, all combined. Artwork by Irina Yurchenko.

potential triggered within 20 seconds of the first shuts the snap trap.

How do these plants process their prey? The entrapped struggling animal repeatedly touches the mechano-sensors, thus triggering trains of action potentials. This mechano-electrical stimulation of the trap initiates the synthesis of jasmonate-type touch hormones, causing the closed trap to seal hermetically and to flood the forming green stomach with a lytic enzyme cocktail.

The insect flesh is covered by a chitin shell, but hydrolases in the green stomach of *Dionaea* degrade the chitin polymer coat (chitinases), as well as proteins, nucleic acids, glycans and lipids from the prey into their respective monomers and dissociate the nitrogen, phosphate and sulphate side groups. The latter, together with minerals such as potassium, are the macronutrients required for plant growth, which in non-carnivorous plants are usually taken up from the soil by transport proteins in the roots of the plant. Interestingly, when in contact with trapped animals, traps express and operate root-type transporters to efficiently absorb prey-derived nutrients. *Dionaea* gland cell transporters shuttle nutrients released by the decomposition of the animal food. In doing so, the *Dionaea* glands are able to take advantage of the steep proton gradient that powers proton-driven solute transporters, so mining the animal food source to the trace level.

What genes are required for the carnivory syndrome? Stimulated by prey animals, carnivores that operate active traps translate mechanical touch into an all-or-nothing travelling nerve-like impulse. This action potential is based on the sequential activation of ion channels that transiently depolarize the membrane potential. Recently, the genomes of the first carnivorous plants *Utricularia gibba* and *Genlisea aurea* were identified. Despite their tiny size, these genomes accommodate the typical number of genes found in other plants, lacking genes encoding animal nerve cell-type ion channels. Interestingly, the ion channel profile of the excitable carnivore *U. gibba* is not much different from that of non-carnivores. Furthermore, there is no evidence that either *U. gibba* or *G. aurea* have highjacked genes from their animal victims to build traps capable of catching fast moving animals. Given that no carnivore-specific genes have been identified so far, flesh-eating plants apparently gained their carnivorous syndrome from how they assemble the proteins that exist in all plants.

How did carnivory evolve? Carnivory developed independently in different plant families. Today, over 630 species from more than a dozen genera have been identified that can live on an animal diet. To reconstitute the emergence of carnivorous plants, genomes of more green flesh-eaters — primitive and advanced — must be investigated. Of particular interest are the genomes of the most advanced hunters *Dionaea musciplula*, its aquatic sister *Aldrovanda vesiculosa* and the closely related *Drosera* species. The secretome of *Dionaea* is dominated by a mixture of different hydrolases and antimicrobial proteins. In terms of homologies to non-carnivorous plants, these genes and their expression patterns exhibit strong similarities to plant defence responses. Plants defend themselves against pathogenic fungi and herbivores by wound-induced jasmonates that trigger defence gene production (including chitinase secretion). Plants in nutrient-poor habitats appear to have turned the sword, modifying their ancient defence mechanisms for feeding on chitin-bearing herbivores.

Where can I find out more?

www.carnivorom.com

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Book review

Our symbionts, ourselves

Mary Beth Saffo

One Plus One Equals One – Symbiosis and the Evolution of Complex Life
John Archibald
(Oxford University Press, Oxford, UK; 2014)
ISBN: 978-0-19-966059-9

Anyone who reads Harry Potter every night with his sons (as does John Archibald) clearly knows a good story when he sees one. And the theme of *One Plus One Equals One*, the surprising revelation of the chimeric nature of eukaryotic cells, is a fascinating story indeed. Building on his own specialist's expertise in this area, Archibald spins an engaging, gracefully written and scientifically substantive tale that will enlighten practicing biologists, historians of science, and non-specialist readers alike. As a scientific detective story, it is equally useful as a window into the process of scientific discovery, especially as applied to the special methodological challenges of deciphering the deep evolutionary history of cellular life. *One Plus One Equals One* is that rare creature of scientific writing: a book that is at once solid science and a good read.

Archibald tells a complex tale that touches variously on evolutionary theory; the biology of endosymbiosis; the fossil record of early life; protist phylogeny and taxonomy; the cellular and biochemical architecture of various microbes, plants and animals; the mechanics of DNA and RNA synthesis; horizontal gene transfer; methods of genomic sequencing; and the biophysical intricacies of photosynthetic and respiratory processes. To introduce this varied and, for many readers, arcane material in a way that is accessible to non-specialists, while still offering intellectual meat to specialists, is not an easy task. *One Plus One* gets off to an editorially uncertain start, opening with elementary-school-level introductions